RESEARCH BULLETIN 969 SEPTEMBER 1964

The Codling Moth in Ohio

Historical and Ecological Aspects

C. R. CUTRIGHT

OHIO AGRICULTURAL
EXPERIMENT STATION

WOOSTER, OHIO

CONTENTS

* * * * * *

AGDEX 211/612

9-64-3M

THE CODLING MOTH IN OHIO
Historical and Ecological Aspects

C. R. CUTRIGHT[1]

INTRODUCTION

This bulletin is intended primarily for the use and information of entomologists and apple growers in Ohio and neighboring states. During the past one hundred years the codling moth has been, in the great majority of seasons, the most severe orchard pest with which growers have had to contend. Even at present, (1964), when highly effective spray chemicals have reduced it to the status of a minor pest, it retains its potential as a most serious orchard problem.

As a background for the presentation of facts and data concerning the codling moth, certain information regarding the apple industry in Ohio must be kept in mind. This is necessary since codling moth history is an integral part of the history of apple growing in the state. Features of the industry such as early locations, rate of growth, centers of production, marketing, apple varieties, climatic areas, types of orchard management, and others, all have influenced the behavior of the codling moth. Because of the close interrelationship of host and pest, a brief summary of the history of apple growing in Ohio as related to codling moth activity is presented in the first section of this bulletin. Other sections deal with the ecological aspects of the codling moth problem.

HISTORICAL

Early Apple Culture in Ohio The first white men who came to Ohio with the idea of permanent residence in the area brought with them the seeds of apple, peach, cherry, and plum. These people came as traders, missionaries, and farmers. Among the first apple trees grown were those in the Maumee Valley, planted by French traders and priests. They were responsible for the so called "Indian trees" on Indian Island and along the left bank of the Maumee River about three miles above Waterville. Following planting of the first seeds by the French, Indians of this area became interested in these fruits and during a period from 75 to 100 years expanded the plantings. It is a matter of history that when General Wayne defeated the Indians in 1794, he inflicted further punishment by the destruction of their corn fields and the cutting down of several thousand of their apple and peach trees(23).

[1]Professor Emeritis, Department of Zoology and Entomology, Ohio Agricultural Experiment Station, Wooster, Ohio.

The Maumee Valley plantings were followed (1762) by those of Moravian missionaries at Gnadenhutten and Schoenbrun in the Tuscarawas Valley. In 1788, General Israel Putnam established the town of Marietta. From this point settlers spread up and down the Ohio and up the Muskingum Valley. These settlers brought fruit seeds and also scions of the better varieties of apples from the east (27). General Putnam was interested in apple growing. It is recorded that in the spring of 1789 he personally grafted a number of trees. Several

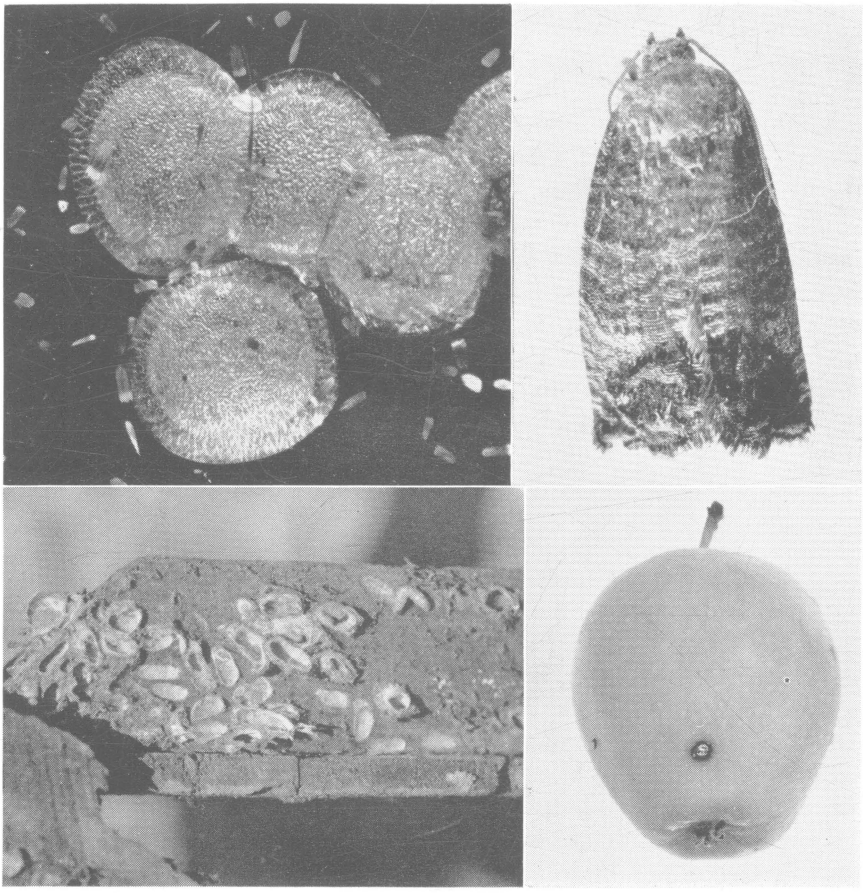

Plate I. Fig.—A. Eggs of the codling moth (greatly enlarged).
Fig.—B. Adult Codling moth (enlarged x 2).
Fig.—C. Codling moth cocoons and larvae on slat of apple crate.
Fig.—D. Codling moth "sting". (A "sting" is an injury produced by a young larva that dies in attempting to enter the apple).

nurseries where improved varieties were propagated were soon established in that area. One of the most noted of these was Putnam's nursery, located near Marietta. About fifty varieties of apples were offered for sale by this nursery. Fruit plantings in the Cincinnati area were also of an early date. Those in the Scioto Valley followed shortly.

In northern Ohio the planting and distribution of the apple were greatly aided by the work of the almost legendary "Johnny Appleseed" (27). This man, whose real name was John Chapman, spent approximately 25 years (1796-1821) traveling over northern Ohio. He planted apple seeds, established nurseries, and later transplanted the trees. For example, near Ashland, Ohio, on land now occupied by the Thorneburg Orchards and Nurseries, Chapman and the owner of the land, Mr. Carter, planted an apple orchard of 30 acres. This is said to have been his largest planting although he started hundreds of smaller orchards. Thus by 1815 the apple had been widely planted in Ohio and in many areas fruit was being produced. However, despite this wide dissemination, orchards were still small and mostly isolated. Since propagation of the apple either from seeds or by grafting is not conducive to spread of pests, many of these isolated orchards for many years remained practically free of insect pests.

Farm Orchards The early settlers in Ohio knew that most of their food had to be produced at home, therefore, many immediately planted apple seeds or seedling trees around their cabins. These were soon followed by use of trees which had been grafted to better varieties though numerous seedling trees remained in production for many years. As the settlers increased in number and new farmsteads were established, the planting of apple trees likewise expanded (27). The farm orchard became a standard feature of rural life in Ohio and planting and care of the apple were common to almost every farm home up to and including the early years of the 20th Century. However, from that time to the present farm orchards have been in continuous decline. Today a few old, neglected trees may be seen around some farm homes. A very few farmers still maintain a few trees and utilize the small amount of inferior fruit that is produced. However, for practical purposes, the farm orchard is a thing of the past.

Virtual disappearance of the apple from large areas of rural Ohio is primarily due to the ravages of diseases and insects. Among the latter, none have been more damaging than the codling moth. The increasing seriousness of codling moth attacks from 1870 to 1920 is shown as paralleling the decline of the farm orchard.

Commercial Apple Orchards The first Ohio area to produce apples commercially was located around Marietta. Some fruit was

shipped up the Ohio River to Wheeling, W. Va., and Pittsburgh, Pa., but a far greater volume went down river to St. Louis, Mo., and New Orleans, La. Later the Cincinnati area also contributed to this traffic which was maintained in greater or lesser degree until shortly after the time of the Mexican War. The decline and end of the river trade in apples was due to several factors, including transportation and production costs, but the principal reason was increasingly large amounts of insect and disease damaged fruit which could not be sold. The codling moth undoubtedly played a part in producing this low quality fruit.

During the 150 years of commercial apple growing in Ohio, the areas or centers of production have changed many times (27). Without going into detail on this point, it may be mentioned that at the time of the Mexican War, the Cincinnati area was producing large quantities of apples. This area expanded and the lower Miami River Valley led in fruit growing and the production of nursery stock. Following the Civil War, the Chillicothe area produced many apples and this has continued in lesser degree to the present time. From 1890 to 1930 two areas would be considered co-centers of production. These were (1) southeastern and southern Ohio (Lawrence County in particular) and (2) northern Ohio (Ottawa and Sandusky Counties and the Waterville area). The areas west of Cleveland in Lorain and Erie Counties should be mentioned. Since 1910, northeastern Ohio and particularly the Columbiana and Mahoning County area, has increased production and now leads the state. Climatic conditions in this area are less favorable to the codling moth than in other sections of the state.

Other areas in the state were at one time or another prominent in the production of apples. For example, Delaware County had numerous orchards but a combination of economics, fireblight, and codling moth ended significant production in this area about 1930. Jackson County has a long record of production and is still producing heavily. It is thought that the isolation of orchards in this county has aided in insect and disease control and hence in production. Washington County has experienced at least three periods of commercial apple growing. The first has already been noted at Marietta. The second was from about 1880 to 1900 and the third from 1910 to 1940. Due to industrialization and other factors, there is only minimum production today in Washington County. Urbanization in counties such as Cuyahoga, Summit, and Hamilton has virtually eliminated apple growing. It is interesting to note that the experience of individual

apple growers in widely separated counties such as Ashtabula, Geauga, Jefferson, Stark, Belmont, Fairfield, Union, Greene, Darke, Van Wert, Ashland, Williams, and others show that the apple can be successfully grown in all parts of the state.

Codling moth damage has been especially important in the decline of apple growing in at least two areas, namely, (1) Lawrence County in which ravages of this insect, coupled with the economics of the depression years (1930-35) forced abandonment of many orchards and (2) the Waterville area where the codling moth alone was the unfavorable factor.

Horticultural Societies Probably the first agricultural society organized in Ohio was at Cincinnati in 1818. Other societies of the same character were also formed in Youngstown and in Washington County at very early dates. While the principal object of these groups was to promote general agriculture, horticultural topics were frequently discussed (23). From groups such as these came the first local, county or area horticultural societies. Unfortunately, very little is known about these early organizations. In many instances, such groups were active for limited periods of time, then disbanded or reorganized in a somewhat different form as to objectives or area to be involved. In 1870, thirteen such societies were listed as follows:

Cincinnati
Ross County, Chillicothe
Loveland, Clermont Co.
East Cleveland
Berlin, Berlin Heights
Muskingum, Zanesville
Clairdon, Geauga Co.
Hocking Valley, Lancaster
Montgomery Co., Dayton
Moscow, Clermont Co.
Erie Co., Sandusky
Warren Co., Lebanon
Belmont and Monroe Cos., Jerusalem

The county societies increased in number, especially in eastern and northern Ohio, and reached a peak in numbers from 1920 to 1930. Since that date, their number and influence have decreased except in a few areas. However, whatever their number or status, the subject of insect control has always had a prominent part in their programs.

The first statewide organization of horticulturists in Ohio was founded at Columbus in 1847 (27). A few years later it adopted the name, The Ohio Pomological Society, which was changed in 1867 to that of the Ohio State Horticulture Society. Among objectives of this group was the study of insects attacking fruits and the development of better methods of controlling them. Due to lack of documentation, little is known of the activities of this early group as to (1) insect control recommendations and (2) amount of damage that was done to the different fruit crops by the various pests. However, statements in papers and letters written by persons interested in horticulture from 1850 to 1865 lead to the belief that the codling moth was present in Ohio orchards, and in some areas was regarded as a serious pest. In 1867, when the name of the Society was changed, an annual report was issued in which notes on insect injury and recommendations for control were included. Such reports have been issued annually since that date and from these fairly accurate accounts of the insect pests of different seasons may be secured.

Entomologists Petitions and resolutions by horticulturists asking that studies be made on fruit insect pests were presented to the legislature almost every year starting in 1867 (27). Finally in 1886, funds were provided and the first entomological work was started at the Agricultural Experiment Station. The names and terms of services of those in charge of this work follow:

W. B. Alwood	1883-1886
C. M. Weed	1888-1890
F. M. Webster	1891-1901
P. J. Parrott	1902-1903
H. A. Gossard	1904-1926
J. S. Houser	1926-1947
D. F. Miller	Chm. 1947-1961
C. R. Neiswander	Assoc. Chm. 1948-1960
G. W. Wharton	Chm. 1961-
R. W. Rings	Assoc. Chm. 1962-

In 1947, the department of Entomology of the Ohio Agricultural Experiment Station was combined with the department of Zoology and Entomology of the College of Agriculture at The Ohio State University. Thereupon, the chairman of the department at the University was placed in overall charge of all zoological and entomological research and teaching. The associate chairman remains in charge of the research work at the Experiment Station and also participates in the activities of the department at Columbus. All of the early entomologists did research work with fruit insects, and especially with the

codling moth. Drs. Neiswander and Rings supervised codling moth projects, but did not work directly with the problem. Research work with fruit insects has been conducted in Ohio every year since 1886 and in practically all seasons the codling moth has had a prominent position in these programs.

Chronological Notes on the Codling Moth in Ohio

The Pre-Spray Era (27) Records of early recommendations for codling moth control are almost nonexistent, but from farm papers that were circulated in Ohio prior to the Civil War it is known that pasturing livestock in the orchard or collecting and feeding dropped fruits to animals was a common practice. Also, some use was made of hay twists or bands[2] which were placed around the tree trunk to trap the larvae. It was recommended that these bands be removed from the trees every 7 to 10 days and burned.

According to the report of the Ohio State Horticultural Society for 1867, "worms" caused a high percentage of the apple crop to fall to the ground. The crop for the state, which included apples from farm orchards, was estimated at 11,637,000 bushels. Recommended control measures for the codling moth were to pick up dropped fruit daily and feed to hogs or boil the fruit in water to kill the worms. Hogs or sheep could be pastured in the orchard to eat the dropped fruit. Dr. Warder, president of the Society that year, also recommended use of hay bands.

The alternation of large and small crops of apples in Ohio was very marked. For example, in 1876 the crop was estimated at 30 million bushels. On the other hand, the crop of 1877 was reported as hardly 10 percent of that amount. Accompanying the reports of light crops were almost always complaints of severe insect injury, usually by the codling moth. Losses due to this pest during low crop years was frequently estimated as high as 50 to 75 percent.

In 1877, codling moth was named in the Annual Report as the greatest obstacle to successfull apple growing in the state. The recommended control again was the keeping of hogs, sheep and poultry in the orchard to destroy the fruit as it fell. The use of folded paper bands was also suggested. Also the use of paris green was mentioned for the first time but not for control of the codling moth. It was to be "syringed" on the trees to kill canker worms.

[2]Hay twists or bands were made by starting with a handful of hay at the edge of a pile of hay or a hay stack and twisting it. As the twist formed the man making it backed away from the stack continuing the twisting. With some practice a twist or band up to 5 or 6 feet in length could be obtained in a few minutes. The author has made such bands which were used in experimental comparison with burlap-faced paper and corregated cardboard bands. In these experiments the hay bands were inferior to the others in that they did not trap as many codling moth larvae.

From 1880 to 1882 paris green and london purple were suggested for use against codling moth and plum curculio and it was definitely recommended in 1883. The method of applying the material was to throw the solution on the trees with a dipper from a filled barrel or hogshead which was mounted on a wagon and driven through the orchard. Different dosages were recommended, a common one being 4 ounces of paris green to 32 gallons of water. Some authorities recommended london purple and the debate between the users of this material and paris green continued until both were replaced by the more efficient and less phytotoxic lead arsenate. This later material was used in New York as early as 1885 but its use in Ohio was not fully established until about 1900 when successful experiments were conducted with it against codling moth and plum curculio.

Era of Spraying Spray machines or pumps were mentioned in the proceedings of the Society as early as 1885 but the first definite reference to them was made in 1887 when J. J. Harrison of Lake County paid $50 for a sprayer with which to fight codling moth. Also mentioned was a spray pump which could be mounted on a barrel and which was placed on a cart for transportation. Cost ranged from 12 to 15 dollars. In 1889, Professor Weed, state entomoligist, in an address before the Horticultural Society stated that hand pumps could be purchased at one to two dollars and a "complete" machine at $75.

By 1893, spraying for the control of insects and disease was well established and the annual report of the Horticultural Society devoted considerable space to a discussion of spray materials (bordeaux mixture and paris green), spray pumps, and suggestions for a spray schedule. Also, an exhibition and demonstration of spray equipment was held at the Agricultural Experiment Station at Wooster with seven firms exhibiting. The gasoline engine was first used to furnish power for spray pumps about 1895. Prior to this a few sprayers were equipped with steam engines.

The first Ohio Spray Schedule was issued in 1897 as part of a bulletin which dealt with disease and insect pests. It contained suggestions for spraying certain vegetables as well as fruits. Paris green or london purple were recommended for use on apple and were to be mixed with bordeaux mixture or lime. Since its first appearance, the Ohio Spray Schedule has been revised and reissued almost every year. Soon after 1898, it was enlarged and together with certain horticultural information was published in bulletin form. This was discontinued in 1958 when it was replaced by use of spray charts.

From 1895 to 1903, Ohio orchards suffered severly from the newly introduced San Jose scale which killed thousands of fruit trees.

Apple growing declined and there was little planting or replacing till around 1910, though a practical control for the scale by spraying with lime-sulfur was discovered in 1903.

The revival of the apple industry was caused by increased demand following decreased production due to the San Jose scale disaster. It was also influenced by (1) the rejuvination of orchards, particularly in southern Ohio by nitrogen fertilizers, and (2) by the records of apple production and profits from orchards in which definite control of insects was secured by following a directed spray program. This latter work was supervised by H. A. Gossard and was especially successful in the control of codling moth.

The general use of lead arsenate, which started around 1900, greatly reduced the injury by the codling moth and most growers and entomologists felt that the problem was solved for all time. This happy condition lasted for almost thirty years, though some injury was reported from 1920 to 1929, particularly in years when the crop was light. This injury was by no means general but did exist in certain orchards.

In 1926 the author was assigned the problem of controlling apple insects and due to such reports of injury by the codling moth, research was undertaken with this pest (6). Afterward, some research of either a biological or control nature was carried on each season.

A detailed account of the activities of the codling moth for each year 1926-1963 inclusive, will be found in the appendix of this bulletin. In summarizing the records of the 37 years during which the author engaged in research with this insect in Ohio, the great differences in infestations that existed from season to season, between areas, and among orchards in the same area, must be stressed. There are, of course, definite reasons for such differences though at times they are far from being obvious.

These reasons will be discussed in more or less detail in the section of this bulletin that deals with ecological factors, and it will be shown that the action of even one factor may be sufficient to tip the balance for or against the insect. In other cases, the interaction of many of the factors may be involved. These annual notes stress weather conditions as a very important factor in control and the data support this conclusion (7). However, it must be kept in mind that the greatly reduced infestations from 1946 to 1964 have been due largely to the introduction and use of new and highly effective insecticides.

CODLING MOTH LIFE HISTORY AND SOME OF ITS ECOLOGICAL IMPLICATIONS

The following general summary of the life history of the codling moth is given as a background for the ecological section of the bulletin that deals with factors affecting codling moth activity.

Figure 1 presents a diagrammatic outline of codling moth life history during a normal year at Wooster, Ohio. This is primarily for the purpose of fixing dates or periods of time during which different stages of the insect are present. It will be noted that there is one full brood and a partial second brood. The spring-generation moths come, of course, from larvae of both broods of the previous season that have overwintered.

The most common location of the overwintering larvae is under loose bark on the tree trunk and larger branches where they have spun their cocoons. However, larvae can also be found in many other positions on the tree, such as in rotten cavities and the splintered ends of

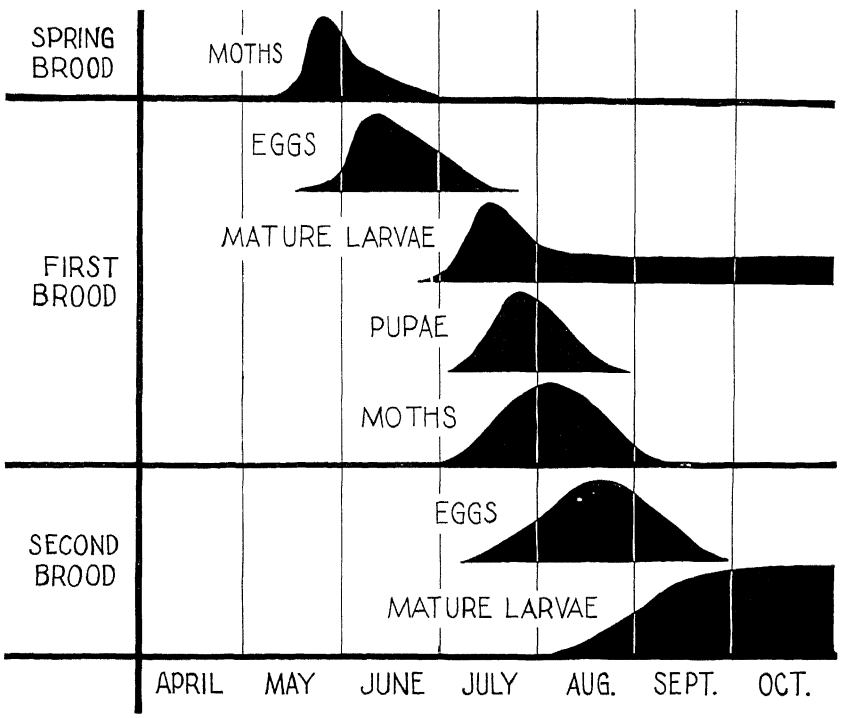

Fig. 1.—Diagramatic outline of codling moth life history at Wooster, Ohio.

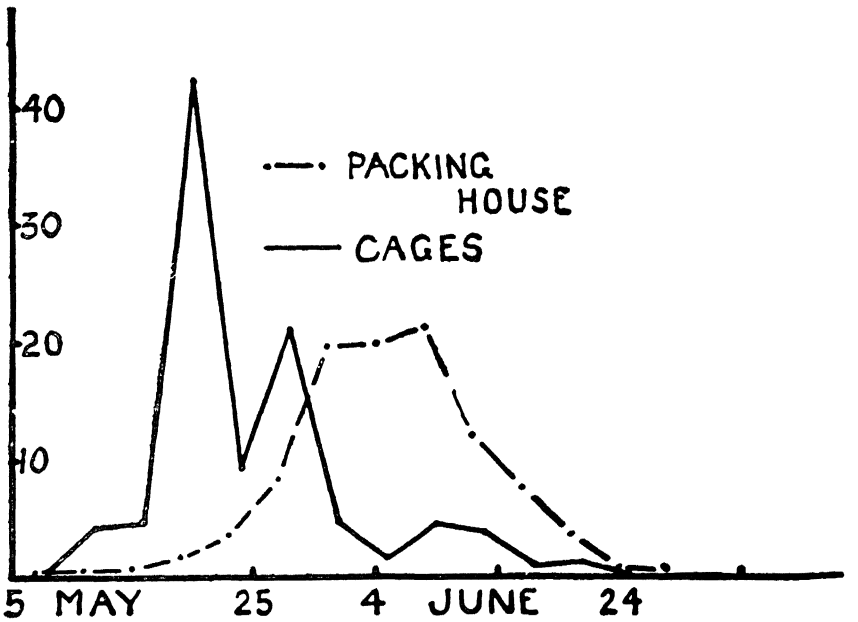

Fig. 2.—Emergence of spring generation moths from outdoor cages (solid line) as compared with emergence from a packing house (broken line). Note the late emergence and late peak of the moths from the packing house.

broken branches. On the ground they can be located on any loose wood, old baskets, old sacks, or in the stems of weeds. A few go below ground level at the base of the tree or crawl into cracks in the ground, where they spend the winter. The mortality among such larvae is quite high, but those that survive emerge later than normal and thus prolong the spray season against the spring or first brood. Overwintering larvae may be found in other situations about the orchard such as buildings or wooden fences. The packing shed is a favorite overwintering site for many larvae that leave apples while the fruit is being packed. Moths emerging from packing houses have an extended emergence period, with the peak much later than normal (Fig. 2).

When exposed to outdoor conditions, larvae remain inactive in the cocoons during the first warm days of spring, but usually in the latter part of April in northern Ohio the first individuals pupate. Temperature has considerable influence on the time and rate of pupation but is not the only factor involved. For example, it is not known why, but larvae under the same temperature conditions pupate at different times. Frequently a period of more than a month will

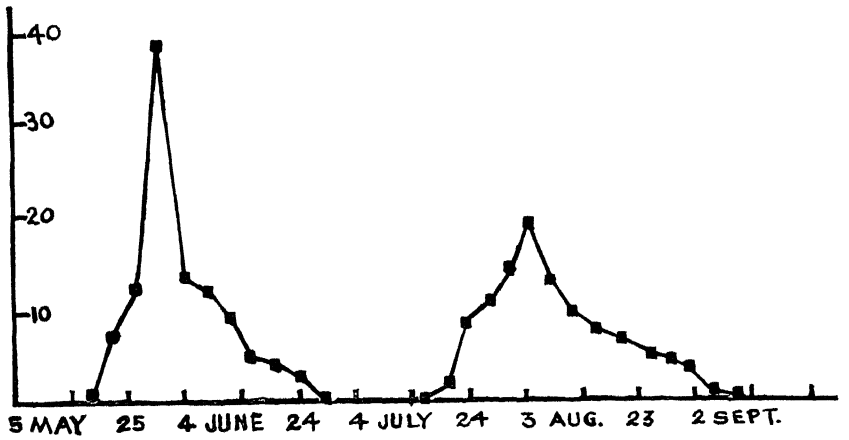

Fig. 3.—Graph showing the average dates of spring generation moth emergence (left) and midsummer brood emergence (right) as determined at Wooster, Ohio, by data taken over a 25-year period.

elapse before all the larvae in a similar habitat pupate. Therefore, because of the different habitats of the larvae, two months may be required for all to become pupae. The length of the period spent in the pupal stage also depends, in part at least, on temperature and may vary from 10 to 20 days.

Before transforming to the pupal stage the larva cuts a circular opening in one end of the cocoon. This is not entirely severed but remains in place held by a small flap or a few silk threads. When emergence time for the moth arrives, the pupa, by vigorously bending back and forth, thrusts itself through this opening to the outside. When the greater part of the pupa is free, movement stops and soon a slit appears along the back and across the head. The moth emerges through this opening. From 10 to 30 minutes or more are required for emergence, after which the moth rests for some time, drying itself before flying away. The great majority of moths emerge from 8:00 a.m. to 11:00 a.m.

At Wooster, Ohio, moths have begun emergence as early as May 1 (Fig. 3) and in one instance as late as May 31. Emergence has ended as early as June 8 and as late as July 10 at Wooster (Table 1). Peak emergence has occurred as early as May 6 and as late as June 5. Once underway, emergence continues from 6 weeks to 2 months. The average length of life of the moth in the orchard is not known. Records of moths in captivity show that the average life span rarely exceeds 10 days, although there are wide exceptions to this rule. Since moths

TABLE 1.—Emergence of Spring Generation Codling Moths, Wooster, Ohio. 1937-1963.

Year	Dates of 1st Emergence	Dates of Peak	Dates of Last Emergence
1937	May 24	May 30	June 27
1938	May 2	May 6	June 16
1939	May 20	May 25	June 21
1940	May 22	June 3	July 5
1941	May 8	May 20	June 14
1942	May 2	May 14	June 15
1943	May 23	May 31	June 25
1944	May 15	May 22	June 11
1945	May 3	May 20	June 8
1946	May 3	May 22	June 16
1947	May 23	May 31	June 20
1948		Incomplete Data	
1949	May 1	May 17	June 10
1950		Incomplete Data	
1951	May 15	May 23	June 20
1952	May 16	May 25	June 16
1953	May 7	May 27	June 28
1954	May 15	May 27	June 20
1955	May 4	May 20	June 25
1956	May 27	June 4	July 10
1957	May 12	May 28	July 7
1958	May 17	June 2	July 4
1959	May 13	May 21	June 14
1960	May 16	May 24	July 3
1961	May 31	June 6	July 2
1962	May 12	May 20	June 21
1963	May 22	June 3	June 5
Average Dates	May 14	May 25	June 18

in captivity show many abnormal traits, it is thought that uncaged moths live considerably longer and that they lay more eggs.

If temperatures and other conditions are favorable in cages, egg laying in greatest abundance usually occurs 3 or 4 nights after emergence. Egg deposition is greatly influenced by temperature. No oviposition occurs if the temperature is below 62° F and only a small proportion as 70° is approached. Above this point the number of eggs deposited may be greatly increased. Also, more eggs are deposited during a period of high temperature than if the weather is cool. Most eggs are laid during the twilight hours and some just at dawn, although at daybreak low temperatures frequently interfere. In the orchard, the eggs are placed on the apples or on leaves close to the fruit.

Egg hatching takes place 8 to 13 days after oviposition, the time being influenced largely by temperature. The young larvae, if hatched from eggs on leaves, wander about until they encounter an apple, after

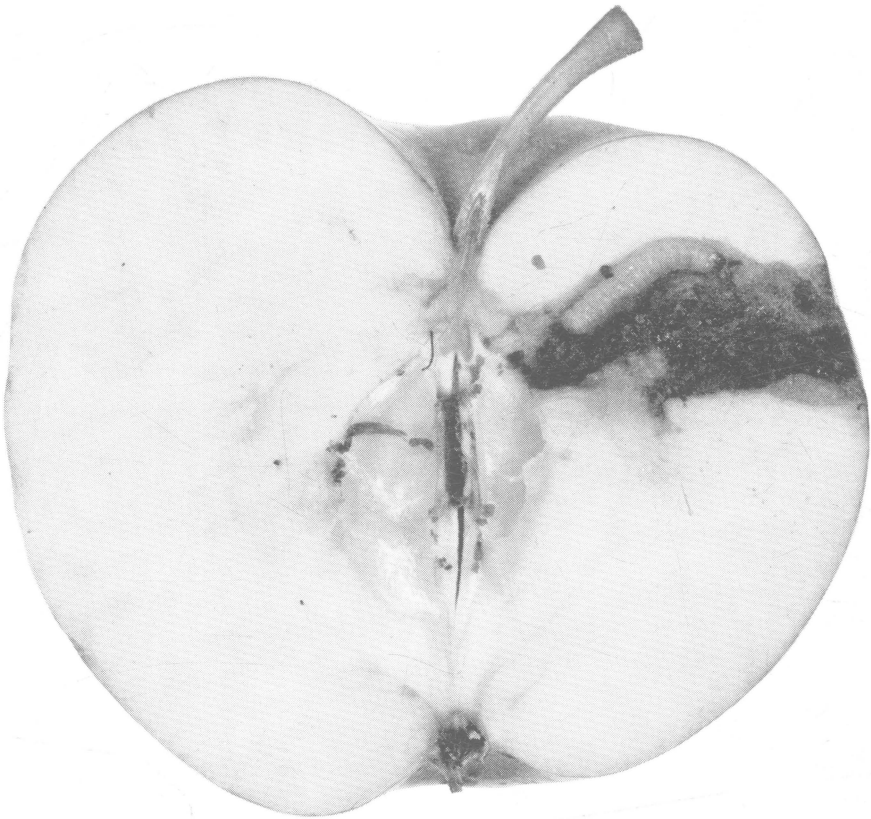

Fig. 4.—Typical codling moth injury to interior of apple. Larvae are frequently found in this position just before leaving the fruit.

which they soon attempt to "chew" into the fruit. Larvae from eggs on the fruits seldom leave the apple but usually attempt to enter after a short time. Not all larvae succeed in entering the apples, even on unsprayed trees. Considerable energy is required by the young larvae to cut through the tough skin of the young fruit, and if they have been weakened by much wandering or by cool weather before finding the fruit, many are unable to enter. Some die without leaving a mark on the apple; others only break the skin, and this finally results in a "sting". Early in the season the favorite point of entrance is through the calyx, but later many larvae attack the sides of the fruit.

Once inside, the larva usually bores directly to the center of the fruit where it feeds on the seeds. The period spent in feeding and growth lasts 16 to 25 days, depending upon temperature. When nearly full grown, the larva cuts a channel to the outside (Figure 4) and leaves

TABLE 2.—Emergence of Summer Brood Codling Moths, Wooster, Ohio. 1937-1963.

Year	Dates of		
	1st Emergence	Peak	Last Emergence
1937	July 19	Aug. 4	Aug. 24
1938	July 12	Aug. 3	Aug. 19
1939	July 7	Aug. 4	Sept. 6
1940	July 22	July 30	Aug. 31
1941	July 11	July 30	Sept. 1
1942	July 13	July 21	Aug. 26
1943	July 13	Aug. 6	Sept. 7
1944	July 5	July 19	Sept. 1
1945	July 23	Aug. 12	Sept. 1
1946	July 18	Aug. 3	Sept. 4
1947	July 28	Aug. 13	Aug. 29
1948		Incomplete Date	
1949	July 10	July 26	Aug. 19
1950	July 18	Aug. 3	Sept. 4
1951	July 21	Aug. 10	Sept. 7
1952	July 7	July 22	Aug. 28
1953	July 8	July 16	Aug. 29
1954	July 9	Aug. 2	Aug. 26
1955	July 12	July 30	Aug. 20
1956	July 17	Aug. 6	Sept. 11
1957	July 8	July 24	Aug. 30
1958	July 20	Aug. 2	Sept. 9
1959	July 10	July 30	Aug. 27
1960	July 13	Aug. 4	Sept. 5
1961	July 22	Aug. 6	Sept. 2
1962	July 2	July 18	Sept. 16
1963	July 22	Aug. 11	Sept. 6
Average Dates	July 14	Aug 1	Sept. 1

the fruit (Figure 5), (Table 3). If the apple is still on the tree the larva may drop to the ground by a silken thread, or it may crawl down the branches to the trunk. Many fall with the fruit to the ground. After leaving the dropped apple, they, together with those that have dropped on threads, move about in ever-widening circles till they find the tree trunk or some other solid, roughened object that offers cocooning quarters. The position selected by all first-brood larvae for cocooning is similar to that of the overwintering larvae, but the time spent in the cocoon at this season by those which give rise to the partial second brood is only 14 to 20 days. In northern Ohio, about half of the first-brood larvae, and particularly those which leave the apple during late July and August do not transform into pupae but continue as larvae through the following winter.

TABLE 3.—Larvae Leaving Apples, Seasonal Dates, Wooster, Ohio. 1937-1963.

Year	Dates of First Appearance	First Generation Peak	Mid-Season Low Numbers	Second Generation Peak	Last Appearance
1937	July 10	July 30	Aug. 23	Sept. 24	Oct. 30
1938	June 25	July 15	Aug. 24	Sept. 17	Oct. 27
1939	June 20	July 14	Aug. 11	Sept. 8	Nov. 7
1940	July 9	Aug. 2	Aug. 26	Sept. 23	Oct. 25
1941	June 21	July 3	Aug. 24	Sept. 9	Sept. 21
1942	June 24	July 22	Aug. 15	Sept. 8	Nov. 3
1943	June 25	July 23	Aug. 24	Sept. 9	Nov. 16
1944	June 18	July 4	Aug. 2	Aug. 31	Oct. 30
1945	July 3	July 27	Aug. 20	Sept. 7	Oct. 6
1946	July 5	July 13	Aug. 6	Sept. 23	Oct. 21
1947	July 7	Aug. 4	Aug. 24	No record.	
1948	No codling moth data in 1948.				
1949	June 26	July 12	Aug. 9	Aug. 29	Oct. 21
1950	July 3	July 19	Sept. 5	Oct. 3	Oct. 31
1951	July 7	July 23	Aug. 24	Sept. 17	Oct. 27
1952	June 23	July 13	Aug. 14	Sept. 11	Oct. 13
1953	June 25	July 23	Aug. 24	Sept. 6	Oct. 28
1954	June 23	July 20	Aug. 23	Sept. 12	Oct. 15
1955	June 25	July 19	Aug. 20	Sept. 1	Oct. 19
1956	June 30	July 28	Aug. 25	Sept. 18	Nov. 9
1957	June 27	July 9	Aug. 18	Sept. 19	Nov. 14
1958	July 6	Aug. 7	Aug. 31	Sept. 16	Oct. 22
1959	June 26	July 20	Aug. 21	Sept. 2	Oct. 20
1960	June 27	July 13	Aug. 26	Sept. 13	Oct. 27
1961	July 4	July 30	Aug. 31	Sept. 24	Oct. 28
1962	July 20	July 6	Aug. 15	Sept. 12	Nov. 19
1963	July 3	Aug. 2	Aug. 23	Sept. 30	Nov. 1
Avg. Dates	June 29	July 21	Aug. 21	Sept. 15	Oct. 27

Those first-brood larvae that pupate in midsummer go through a cycle much the same as already related (Table 2), except that the higher temperatures of summer accelerate the development of all stages. The incubation period of the eggs and the resting period of the pupae are shorter and the moths and larvae require less time for their activities.

Figure 1 may be used also to represent codling moth life history in other sections of Ohio. In the southern part of the state the time period occupied by each stage is about 7 to 10 days earlier than shown. Also, in certain seasons, part of the second-brood larvae pupate and moths emerge, giving rise to a partial third brood of larvae. In northwestern Ohio the time periods are 2 to 6 days, and in northeastern Ohio 4 to 8 days later than the diagram indicates.

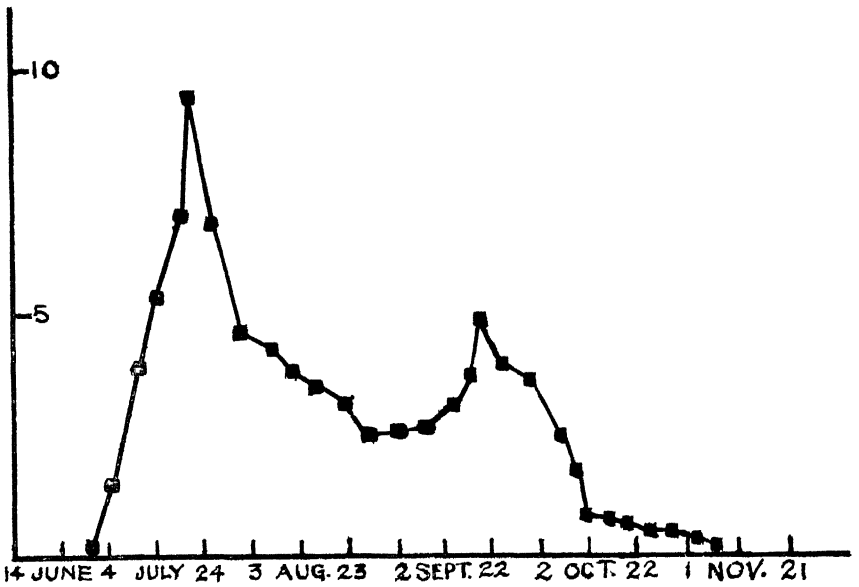

Fig. 5.—Graph showing average dates for codling moth larvae leaving apples as determined by data taken at Wooster, Ohio, over a 26-year period.

ECOLOGICAL FACTORS THAT AFFECT CODLING MOTH ACTIVITY

Climatic Conditions

In the first studies of injurious insects made by economic entomologists, it was soon determined that climatic factors were highly important in the life history of the pest and the amount of damage. Conditions in one area may favor an insect and permit large amounts of injury while in a different climatic situation they will act as a control.

The response of the codling moth to climate is definite. This insect was first known in Asia Minor, where its favorite host, the apple, originated and it has followed this fruit to all areas where it is produced. However, in cooler areas where the apple is grown, the codling moth is not as damaging as it is in sections where seasonal temperatures are higher. Similarly, in a given area, codling moth injury may be severe one year but due to different, primarily cooler, weather conditions damage may be greatly reduced in another season.

Since "climate" is made up of numerous weather factors, the more important of these will be considered individually as to their effect on codling moth activities.

Temperature When considered either alone or in combination with the other climatic elements, temperature is the most important factor that influences codling moth behavior. This is shown by the references to temperature conditions which constantly appear in literature dealing with this insect. For example, Isely and Ackerman (21) have shown that eggs are not deposited by the codling moth when temperatures fall below 62° F but that as temperatures increase above this point, eggs will be laid at a correspondingly higher rate. Cutright (5) showed that as temperatures increase within a range of from 65 to 85° F young larvae are enabled to enter and establish themselves in the fruit in proportionately greater numbers. Glenn (14) demonstrated that certain numbers of thermal units (days-degrees) above a developmental zero are necessary for completion of growth of any of the four stages of codling moth life history. Isely and Schwardt (22) and Cutright (6))working independently, secured data which showed that temperatures above normal in late May and early June practically always preceded difficulties in control (Figure 6). Numerous other illustrations of the importance of temperature could be cited from the literature. In summarizing the importance of temperature, it may be said that if high temperatures prevail throughout the growing season adult codling moths will emerge earlier in the spring and will deposit a greater number of eggs. These eggs will hatch earlier in the season and the larvae will be more vigorous and active, and will succeed in finding and entering fruits in greater numbers. Within the fruit, they feed more voraciously and become fully grown at an earlier date. They leave the fruit, succeed in finding cocooning quarters, and again the moths emerge earlier. This acceleration of first brood development means that the second brood attack comes earlier with larger numbers of moths to lay eggs and, if high temperatures continue, all activities continue to proceed at the same rapid pace. In cool seasons all processes are slowed and impeded, thus aiding in control. However, in seasons with alternating hot and cool periods the codling moth will take advantage of every warm period, particularly if eggs are hatching and young larvae are attempting to enter the fruit. Even one warm week in such a crucial period may be enough to cause trouble.

Accurate knowledge of temperature conditions as they exist in this area are a definite aid to the grower. If average temperatures exist, the usual interval between spray applications should be observed. However, if temperatures above normal occur, the period between sprays should be shortened. For example, if 14 days is the usual interval between sprays and temperatures are averaging from 2 to 4

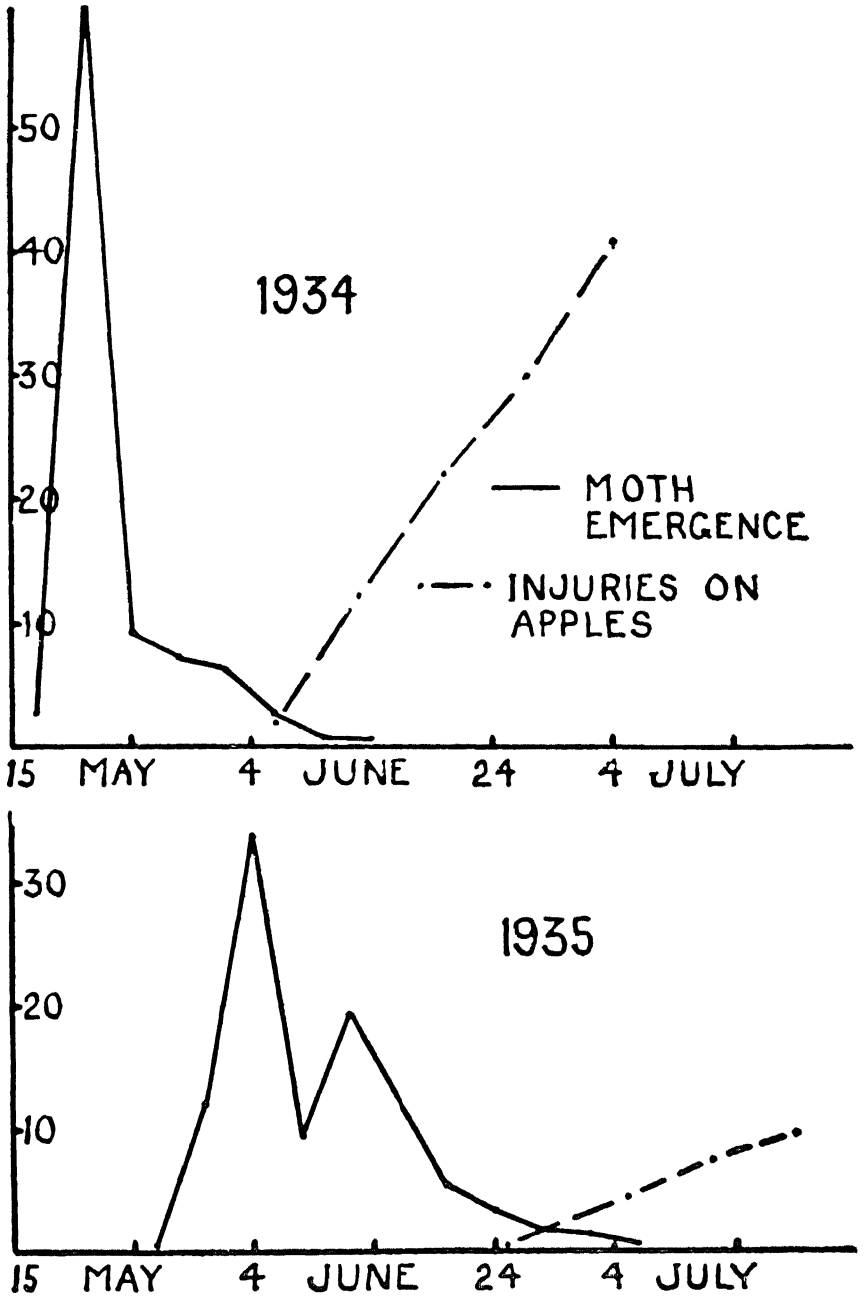

Fig. 6.—Moth emergence and rate of appearance of injured apples as affected by seasonal temperatures, 1934 had high temperatures in May and June while in 1935 temperatures were low.

degrees above normal, then the interval should be shortened to no more than 12 days. If the average is 6 to 8 degrees above, then the interval should be no more than ten days.

Rainfall A statement frequently made is that "hot and dry" seasons favor the codling moth. This would imply that seasons with abundant rainfall would not favor the insect. However, data show that many wet seasons are also those in which codling moth has been severe, as for example, in 1931, 1934, and 1944. However, in general, heavier infestations seem to occur in dry years. Another effect of rainfall has been demonstrated by Shelford (34) who showed that rains occurring when the insect is in the pupal stage actually speed up the rate of development. During periods of rainfall flight is very much restricted and moths seek shelter under the surfaces of leaves.

Humidity A two-year study in Lawrence County, Ohio of ecological factors affecting the codling moth showed that humidities were far lower in the hill orchards than in those located on the valley floor (Figure 7). Also, the study showed that the codling moth was far more severe in the hill orchards. Since orchards grown in arid locations such as those in the western states have been subject to severe

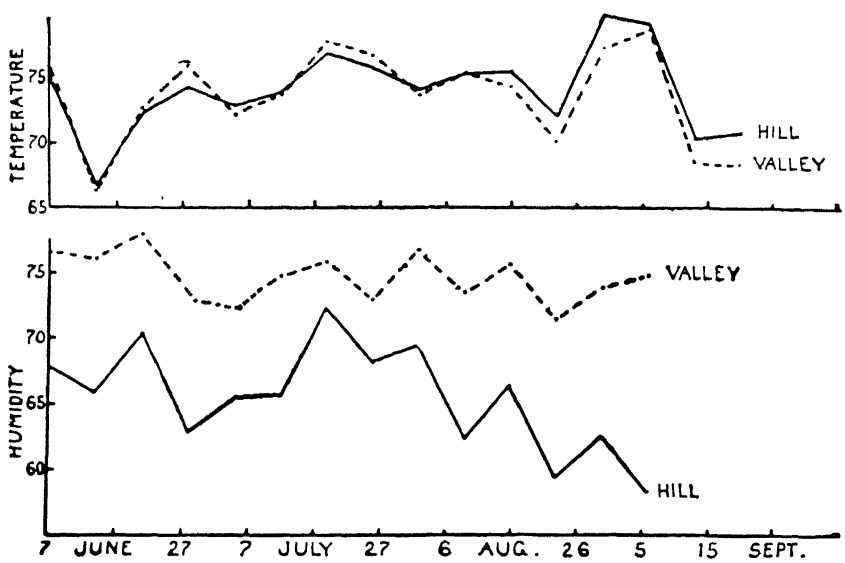

Fig. 7.—Comparisons of temperatures and humidities occurring in hill and valley orchards. Lawrence County, Ohio. Data by C. H. Huff, 1933.

codling moth attack and since dry years are reported to favor the insect, it would appear that low humidity might be a factor. However, the very definite data secured in Lawrence County are complicated by other factors such as inadequate spray coverage due to lack of water and a very heavy initial population of overwintering larvae which existed in the hill orchards. Therefore, no definite statement as to the effect of different degrees of humidity can be made at the present time.

Evaporation Temperatures greatly influence the amount of evaporation, therefore, seasons with higher evaporation rates tend to favor the increase of codling moth damage. However, if evaporation is considered alone and within its usual ranges, it probably has relatively little effect on codling moth activity.

Wind During periods of brisk winds or storms, codling moths seek shelter under leaves; and, as in the case with rainfall, flight is greatly reduced. In highly infested orchards, during evenings with temperatures of 70° F or more when calm prevails, moths may be seen making numerous short flights around the tops of the trees. If a light breeze is blowing, moths tend to drift with it from tree to tree and finally will arrive at the edge of the orchard. When wind carries them beyond the apple trees, they turn and fly back. This accounts for heavier infestations that are frequently noted in the outside rows on the leward side of the orchard. Therefore, winds play a definite part in distribution of moths in the orchard.

Light The intensity of light is an important factor in the behavior of the codling moth. During the daylight hours when light is most intense, moths are quiescent. However, as dusk approaches and if temperatures are favorable, activity starts and will continue to the time of total darkness. The peak of flight, mating, and egg deposition usually occurs shortly after sunset. Another peak occurs during the early morning hours but due to lower temperatures this is not as marked as in the evening. Where codling moths are being reared under laboratory conditions, finding the correct biological intensity of light is frequently a difficult problem.

Nonclimatic Conditions

Factors Favoring the Codling Moth

Monoculture In relation to the apple industry the term monoculture, is applied only to the area that is entirely occupied by the apple trees.

Monoculture is the only possible economic system for the production of the great majority of our crops and there is no tendency to dis-

place it. However, it has some decided disadvantages, especially in the field of pest control. Monoculture in the production of annual crops is not as serious as is the case where the crop must occupy the ground for a period of from 30 to 40 years. Where the annual crop is involved, it is always possible to practice rotation of crops and thus avoid the buildup of numerous pests. This is not the case where perennial fruit crops such as the apple are involved. In apple culture, and especially where large areas are used, the situation is ideal for the propagation of pests, whether they are diseases, insects, or mites. A constant and abundant supply of food for pests is the great disadvantage that long-time monoculture suffers. If the crop is small or absent on one tree, other trees are close at hand and can be reached without the hazards of long migration. Shelter is available everywhere. Thus by the very nature of economic apple production conditions most favorable for insects, mites and other pests are established. Thus, special and additional procedures must be used for the control of pests.

Annual Bearing Another economic necessity in fruit growing is that a crop of fruit be produced each season. No crop or a small crop in alternating years has meant economic disaster to many growers. Fortunately for the apple industry, modern practices such as fertilization, the use of less phytotoxic sprays, chemical thinning, and better cultural practices have largely eliminated the disadvantage of biennial bearing.

However, the fact that fruits are present in the orchard each year is decidedly in favor of the codling moth and other fruit-infesting species. One of the reasons that codling moth was not serious in pioneer days was the biennial bearing habit of many of the seedling trees. This added to the fact that non-fertilized and generally uncared for trees are more subject to frost damage to blossoms brought about many seasons without a crop and the codling moth was literally "starved out." Many such instances of nature may be cited even in recent years. For example, in 1927, 1938, and 1944 severe frosts destroyed the entire crop in numerous orchards in southern Ohio. Following such instances, there was almost a total absence of codling moth injury during the next year and marked reduction even in the second season following the frosts.

Annual bearing is of such economic importance that it must be nurtured even though it favors the codling moth and other pests. More efficient control programs must be employed to counteract this advantage that must be given to the codling moth.

Light Crops In horticultural literature statements are made frequently that the light crop of a particular year was severely damaged

by the codling moth (35). There are two reasons why this is true: (1) There are comparatively fewer fruits for the same number of insects to attack and therefore the percentage of injured fruits is much higher and more noticeable; (2) The grower almost always neglects a light nonprofitable crop and thereby permits the development of a greater number of insects than would normally occur.

In almost every orchard there may occur a season in which the crop is so light that it will not pay the cost of adequate protection by spraying. Such a condition may be met (1) by spraying at a loss, (2) by thinning off all fruits early in the season, or (3) by simply abandoning the crop.

Experiences in Ohio from 1930 to 1960 shed some light on the best possible course to follow during short crop years. Several orchards have been observed in which spraying was continued throughout the season at a considerable monetary loss. Some of these growers believed that overall, they were better off by following this course, since codling moth build up in the orchard was prevented. Others later stated that they could have abandoned the crop or thinned off the fruits to advantage.

Results of thinning off the crop have been observed in a few instances. For example, in 1945 a large block of 17-year old trees in Ottawa County set only a few fruits, estimated at about 2 percent of a normal crop (7). Spraying was stopped after petal fall and in late June workmen went over all trees removing visible fruits. From 1 to 110 fruits per tree were removed from 249 trees at a cost of $36. The grower estimated that the cost of spraying for the remainder of the season would have been about $250 for a crop that would not have paid the expense of harvesting. However, it was later estimated that the workmen missed about 1600 fruits and of these almost half were wormy. The trees set a light crop the following season which was sprayed and which at harvest time was 4 percent infested by codling moth.

Orchards with light crops that were abandoned completely were also observed and particular attention has been paid to infestations that developed in the following season when spraying was resumed. The principal objection to abandoning a crop without thinning off the fruits is the assumption that pests will increase unduly and prove troublesome in the following years. Ohio experiences have not supported this assumption. In general when spraying was resumed, the control of pests and particularly of the codling moth has been just as good as in former years. Since we now have a number of very effective

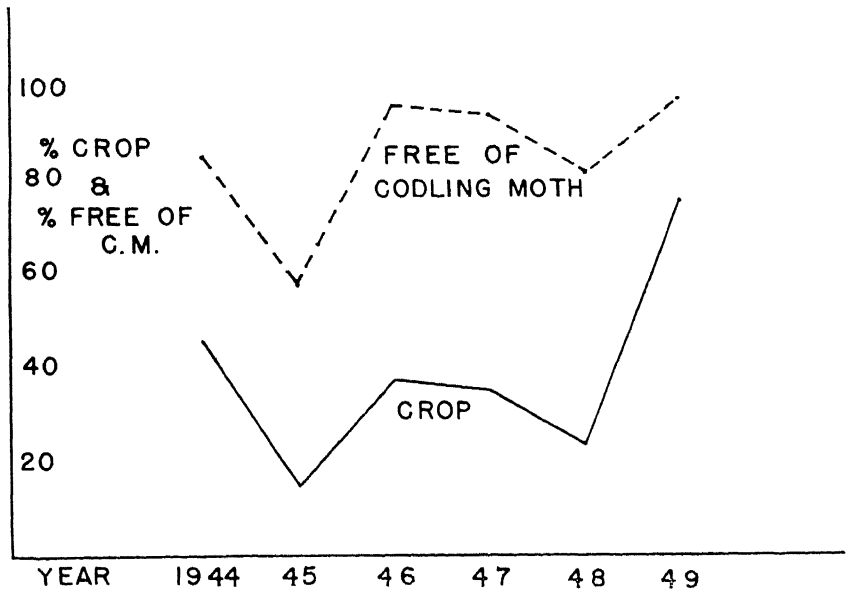

Fig. 8.—Correlation between the amount of crop and percent of the crop free from codling moth damage. Ottawa County, 1944-1949, inclusive.

insecticides it is felt that the abandonment of a crop is not a serious matter. In cases of abandonment, enough fungicide sprays should be applied to protect the foliage from disease and occasionally an insecticide may be needed to control some of the leaf-feeding insects.

Concentration of Apple Orchards This factor favors the codling moth in much the same way as does monoculture. In fact, it could be said that it is an amplification of the disadvantages of that system. Studies in Ottawa County, Ohio from 1944 to 1950 showed that Bay Township where a large percent of the land was devoted to apple growing (Figure 9) had much more difficulty in controlling codling moth than did Salem Township where orchards were smaller and more isolated (Figure 10).)

In areas of concentrated plantings, the codling moth and other orchard pests have unusual advantages of (1) abundant food, (2) available shelter, and (3) lessened difficulties of dispersal. It is of interest to note that since the studies of 1944-1950 many orchards in Bay Township have matured and have been abandoned or removed. There have been practically no new plantings, likely because of the unfavorable experience in insect control.

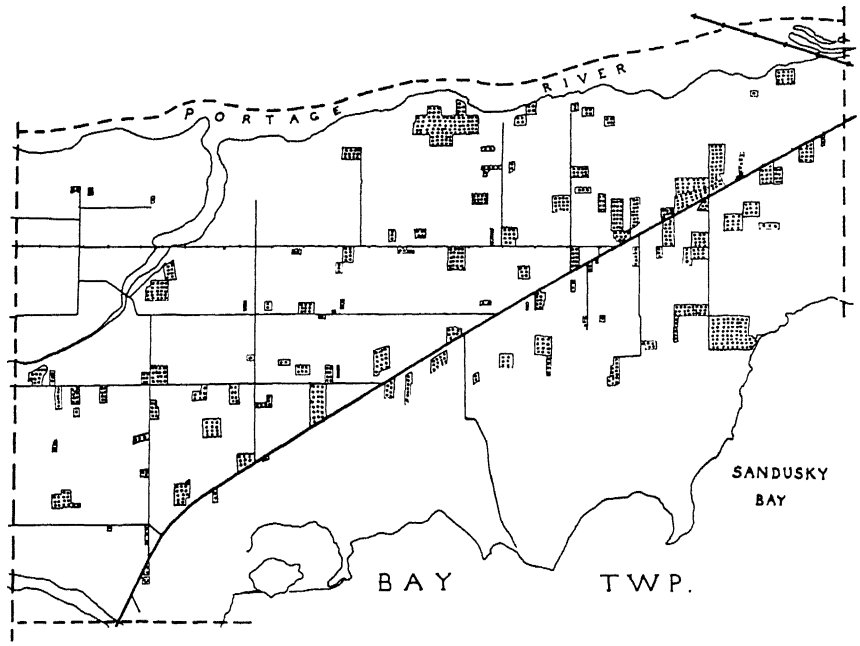

Fig. 9.—Map showing the numerous, large orchards in Bay Township, Ottawa County. Where orchards are large, numerous, and adjacent, more difficulties in codling moth control may be expected.

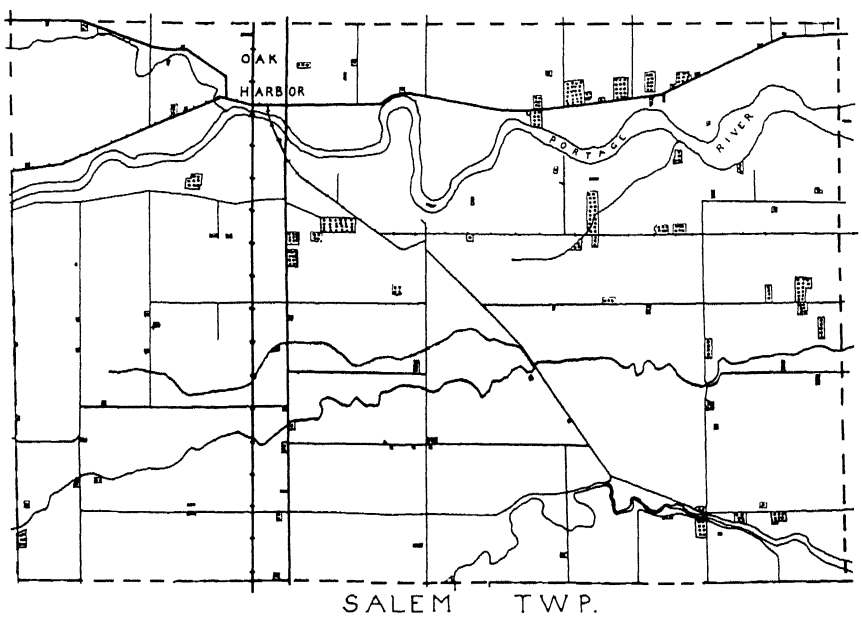

Fig. 10.—Apple orchard in Salem Township, Ottawa Co. Note the small orchards most of which are widely separated. Codling moth control in this township has not been a difficult matter.

Large Trees In Ohio one of the principal characteristics of old orchards is the large size of the trees. Theoretically one should be able to control insects and other pests just as effectively on large trees as on small ones. The difficulty of effectively distributing spray material over the much larger area of the old tree is a purely mechanical matter but one that frequently results in poor insect control. In 1952 an orchard in eastern Ohio was observed in which a block of young trees was located between blocks of large old trees. All blocks had received the same spray schedule, applied at the same time. However, in the blocks of large trees, codling moth injury of fruits amounted to about 10 percent of the crop, while in the block of younger trees injury was less than 2 percent.

In addition to difficulties in pest control, old trees are frequently low in production and the fruit is costly to harvest. Therefore, as an orchard approaches 35 years of age, serious thought should be given to the idea of its removal. However, if it is desirable to retain the trees two things may be done to alleviate the problems of insect and mite control. Trees may be reduced in size by pruning and a more thorough spray program may be devised and applied. The spray program that is necessary in old orchards must include efficient spray chemicals used at minimum dosage and applied in generous amounts. Special care must be taken to see that all parts of the tree are covered with the spray. For rapid and efficient coverage of old trees, a large capacity spray pump is desirable though not absolutely necessary. If time is available, a thorough spray job may be achieved with a smaller sprayer. Where automatic and airblast sprayers are used special care must be taken to adjust the nozzles so that the tops of the trees will be covered.

Varieties All varieties of apples that are grown commercially in Ohio are susceptible to attack by the codling moth. However, there are degrees of susceptibility to the extent that attention should be given to this factor. Probably the most severely attacked variety is Chanago, a sub-acid, tender-skinned, late summer variety. On a single fruit of this variety, more than twenty codling moth entrances have been observed despite the fact that six sprays of lead arsenate had been used. In orchards where the codling moth had become resistant to lead arsenate, the varieties McIntosh and Cortland were much more severely injured than Rome or Jonathan. Further information regarding varietal susceptibility may be found in publications by Isely and Ackerman (21), Newcomer (30), Webster (37), Cutright and Morrison (10), Felt (13), Chandler (2), and others.

In general, the effective spray materials of today permit the growing of even the most susceptible varieties without undue loss to the codling moth.

Interplanting The interplanting of apple orchards with other fruits adds to the difficulties of pest control. This is especially true when the interplant is host to the same general group of pests as the apple. For example, apples and peaches are common hosts for insect pests such as plum curculio and the oriental fruit moth. Numerous cases have been observed in which extra injury to apple has occurred in interplanted orchards. For example, when early peaches are harvested both pests will move to apple where feeding occurs. In the next season these pests are present to again attack the peaches.

The difficulty of control is due to the confusion and extra labor needed to apply different spray chemicals, at different times, to the two plant hosts.

Even the interplanting of early and later varieties of apples may lead to the same general type of trouble. For example, where Yellow Transparent is interplanted with late varieties such as Rome, codling moth will move to the late variety following the harvest of Yellow Transparent. Fortunately the effective spray chemicals of today render the interplanting of early and later varieties of apples less objectionable than was formerly the case.

Heavy Initial Populations The number of moths that successfully emerge following the pupation of overwintering larvae is considered as the initial population for the oncoming season. If this population is numerous, chances for severe damage are much greater than if the population in low. Since numbers present is a factor of importance, it is necessary that some method of determining the population be known. Possibly the most accurate and simple method to use is based on the amount of damage caused by the codling moth during the previous season. For example, if the crop of fruit was large and was damaged to the extent of 0.5 percent, this would mean a relatively low initial population. However, if the damage amounted to 5.0 percent, a serious problem might develop due to the much greater number of insects that would be present. With a light crop, 1.0 percent injury should not be too alarming, but if the damage were 10 percent, then the opposite condition would exist.

In all cases it should be borne in mind that weather conditions affect the development of the population. Favorable weather may increase the damage done by a low population while unfavorable condi-

tions will decrease the harmful effects of a high population. Nevertheless, the initial population should always be taken into account.

Orchard Sanitation Poor sanitation exists when favorable locations for the cocooning and hibernation of codling moth larvae abound in or near the orchard. Nature provides some of these situations, such as the rough bark on the trunk and large limbs of the trees, splintered ends of broken branches, acute crotches, cracks, and holes in trunks and branches. Others are created by man, for example, buildings in the orchards, piles of props, firewood or brush, coarse weed growth, coarse mulch material such as cornstalks or corn cobs, baskets, boards and other debris left in the orchard. The packing house, particularly when located in or near the orchard, provides excellent hibernating quarters for larvae.

The conditions imposed by nature can be corrected and in the past stress has been placed on the scraping and banding of trees. Yothers and Carlson (38) and others have done extensive experiments in this field. This work has been summarized and together with a complete bibliography on this subject is given in their publication (38).

Man-made conditions favorable to the insect can also be corrected. Some need never exist and others can be removed or avoided with little effort. Buildings should never be established in the orchard unless other factors make it highly important. The packing house should be constructed so that it can be tightly closed or screened during periods of moth emergence to prevent moths flying into the orchard.

At this time the spray chemicals used against the codling moth are so effective that sanitation is being neglected and under these conditions it is not as important as in the past. How long this happy situation will last is not known but principles of sanitation should be kept in mind.

Harvesting Practices In harvesting or handling the crop, very few growers will collect the dropped fruit more than once, this usually being done at picking time. Both picked and dropped fruit are usually promptly taken from the orchard to the packing plant where they may remain for varying lengths of time before final disposal. If this time is of long duration, larvae that are in the fruit will complete their growth and leave the apples, following which, they find cocooning quarters in the crates or baskets or in various places in the packing house. If the packing house is in or adjacent to the orchard, the moths originating from these larvae will fly into the orchard and thus add the the difficulty of control. Therefore the prompt packing or disposal of all fruit is highly recommended.

Resistance to Insecticides The ability of the codling moth to develop resistance to the lethal action of certain spray chemiacls has greatly increased the difficulties of control in many orchards and apple growing areas. During the years from 1920 to 1930 increased injury by the codling moth in orchards sprayed with lead arsenate led to investigations by Hough (18) which showed that larvae from some areas in the United States were definitely resistant to this chemical. Later research, also by Hough (20), showed that a resistant strain of codling moth could be developed from a non-resistant strain by subjecting the survivors of each generation to continuous treatment with lead arsenate. It is now recognized that the principal reason for the serious infestations by codling moth from 1930 to 1945 were due to resistance to lead arsenate.

This problem was solved, temporarily at least, by the introduction and use of DDT in 1945-46. However, as early as 1951 there were indications of resistance to this chemical and in 1953 Cutright (8) conclusively demonstrated resistance by the codling moth in an extensive field experiment in the Cincinnati area. Hamilton (15) later confirmed this finding by laboratory tests and also produced proof of DDT resistance in other areas. By 1958, many growers in southern Ohio were abandoning DDT and using other chemicals for codling moth control. However, in northern Ohio, where DDT has been used less extensively it is still effective in many orchards. The materials that are now in majority use against the codling moth, namely Guthion and carbaryl (Sevin)), are as yet fully effective and no reports of resistance to them have been received.

Factors of Little Importance

Soil Types In early considerations of the different factors that might influence codling moth activity, some thought was given to soil differences. During the 35 years of work with the codling moth in Ohio, data have been taken on this point and it is evident that there is no correlation between either heavy or lightly infested orchards and the soil type on which they are located.

Soil Management The great majority of apple orchards in Ohio are grown in (1) sod or (2) sod plus mulch which usually consists of straw or hay. A few orchards are cultivated at certain times. In the case of orchards grown in sod, the natural vegetation, grass or weeds, grows under the trees except for a small area around the base where vegetation may be kept out by mechanical or chemical means. Coarse mulch materials such as cornstalks, corn cobs, or heavy weed growth are occasionally used, and as previously mentioned, may serve as

cocooning quarters for codling moth larvae. However, no correlation between rates of codling moth infestation and systems of soil management has been found.

Fertilization Many different fertilizing materials in different amounts and applied by various means are used in Ohio orchards. None of these seem to influence damage by codling moth.

Factors that Aid in Codling Moth Control

In presenting factors that aid in codling moth control, it should be remembered that the lack or imperfect practice of the factor may be decidedly unfavorable to good control. For example, the unfavorable aspects of poor orchard sanitation and harvest practices have already been presented. Good sanitation and good harvest practice are, of course, aids in control. Other factors may also be hindrances or aids, according to the way they are practiced. The following discussion deals with several of these factors presented in their favorable aspects.

Pruning This is a highly useful practice from many viewpoints. It removes excess bearing wood and opens up the tree to light and better air circulation. A tree pruned according to the best horticultural practice is easily and effectively sprayed since it permits the ready entry of the spray to all parts of the tree. When mechanical, air blast, or "speed sprayers" are used, a well-pruned tree is essential if the most effective results are to be secured. This is especially true in regulating the height of the tree which certainly should never exceed 25 feet for effective spray coverage. While insect and disease free fruit may be produced on poorly pruned trees, the excess spray materials and labor that are required justify the time and expense necessary to prune the tree properly.

Thinning Infested Fruits Thinning is usually considered as the removal of excess fruits so that those remaining may attain good size and color. Incident to this removal, fruits that are infected by disease or infested by insects are also detached. In some cases these are simply dropped to the ground, but the better grower removes them from the orchard and destroys them. Due to high labor costs, hand thinning has now been largely replaced by the use of special chemical thinning sprays, though in some orchards a follow-up, hand thinning operation is done. When this occurs, it is strongly advised that all infested apples be removed and destroyed. This practice will reduce the population of codling moth and other pests and thus aid control.

Nature Enemies (1) **Predators** While in the larval, pupal and adult stages, the codling moth may be attacked by small animals, birds,

spiders, and predaceous insects. These attacks are of biological interest but unfortunately they are rarely of economic importance. Mice will devour codling moth larvae when they are available; as for example, when larvae in numbers are stored over winter in a cold insectary. In the field where hibernating larvae are concentrated around the base of stakes, posts, or trees, a few cases have been observed where cocoons were destroyed in much the same manner as those attacked in the insectary. This was probably the work of mice. In captivity a short-tailed shrew readily ate larvae when they were placed in the cage with it.

Practically all entomologists who have worked with the codling moth have noted the destruction of larvae overwintering on the tree trunk by woodpeckers (25). These will greatly reduce the numbers of larvae above the snow line. Other birds may also be involved. For example, in the early spring of 1945, a large flock of crows invaded the Frank Farnsworth Orchards at Waterville, Ohio and worked over practically every apple tree in search of larvae. So thorough was the destruction that is was very difficult to find a living larvae above the ground. The abundance of larvae that were present before the crow attack was shown by the fact that 17,093 larvae were collected from 115 trees during the previous (1944) season.

Spiders have been observed feeding on larvae which they had captured and carried to the center of their webs.

In codling moth literature, there are frequent references to predaceous insects (1), (17), (3), (33), but little detail is given. Among those mentioned most frequently are ground beetles (Carabidae), tiger beetles, (Cicindelidae), predaceous bugs, (Reduviidae) and ants (Formicidae). In Ohio a small black beetle, *Tenebroides corticalis* Melsh, has been frequently seen attacking codling moth larvae and other isolated cases of predation have been observed. As already noted, the economic effect of predation is very rarely of importance.

(2) **Parasites** Spectacular success in the control of a few insect species by parasites has led to a great deal of work with these beneficial forms. The codling moth is attacked at different times and in various areas by numerous parasites, of which many have been investigated as to their possible use in economic control work (24), (31).

It is known that most of our beneficial insects, both predators and parasites, suffer high mortalities when exposed to spray schedules such as are in common use in apple orchards. Therefore, if the use of beneficial insects is to be successful spray programs must be greatly altered, either by (1) reducing the number of spray applications, (2)

the use of materials nontoxic to the parasites, or (3) the development of parasites resistant to chemicals. This has been done in most of the field experimentation but even under these favorable conditions no striking success has been achieved. A degree of success has been reported by Pickett and associates (26) (31) in Nova Scotia and New Brunswick in Canada; but the degree of control secured is not satisfactory to most growers in the United States. At the Ohio Agricultural Experiment Station, a record of parasitism of codling moth larvae in an orchard where no insecticides were used and in which the fungicide, Glyodin, was applied only in the beginning of each season has produced results of academic interest. This record has been taken annually for a period of over 25 years (Table 4). During all this time, the highest percent of parasitism by all species per year was 8 percent and the lowest 0.3 percent. The average for the entire period was less than 4 percent per year (Table 4). The result of this work, conducted under conditions highly favorable for the parasites has been anything but encouraging. In Ohio orchards where intensive spray programs are applied, parasitism is still present. However, records taken over a period of several years indicate that the percentage of codling moth larvae that are attacked is considerably less than in unsprayed orchards.

A small hymenopteron, *Ascogaster carpocapsae* Vier., is by far the most abundant parasite of the codling moth in Ohio. It deposits its eggs in eggs of the codling moth. The parasitic larva enters the body of the host larva before the latter hatches. After hatching, the parasitized host larva attacks and feeds on the fruit but dies before pupation. Cox (4) has worked out the life history of this parasite in considerable detail.

Another interesting parasite is the very small *Trichogramma minutum* Riley which also deposits its egg within the egg of the codling moth. However, the young host larvae that are attacked die before hatching. A great deal of work has been done with this species in states to the south of Ohio, but the results have been of little economic value.

Parasites from the genera *Macrocentrus* and *Glypta* have also been reared from codling moth larvae in Ohio.

(3) **Nematodes** Codling moth larvae are also attacked and killed by certain nematodes. Some work has been done (11) (12) with these species as biological control agents, but no practical results have been secured.

(4) **Diseases** Larvae and pupae of the codling moth may be attacked and killed by several fungal diseases (36). Unfortunately there are also a number of saprophytic fungi which invade the bodies

TABLE 4.—Percent of Caged Codling Moth Larvae that Emerge as Moths, that Die in Cocoons, Die as Pupae, and are Parasitized.

Year	Percent Emerged	Percent Larvae Dead	Percent Pupae Dead	Percent Parasitized
1937	80	7	4	4.0
1938	70	14	10	6.0
1939	78	16	5	.3
1940	75	20	3	2.0
1941	76	15	7	.3
1942	79	15	4	1.0
1943	87	4	1	8.0
1946*	84	10	3	2.0
1949	79	11	9	5.0
1950	83	10	1	7.0
1951	61	34	2	2.0
1952	68	23	6	7.0
1953	66	18	9	8.0
1954	65	19	9	7.0
1955	82	9	4	5.0
1956	79	9	8	4.0
1957	70	22	6	3.0
1958	52	42	4	2.0
1959	74	20	4	2.0
1960	75	18	3	4.0
1961	73	19	6	2.0
1962	45	50	3	1.4
Average Percent	73%	18%	5%	4.0%

*No records of parasitism were taken in 1944, 45, 47, and 48.

of larvae and pupae after they have died from other causes. To separate the saprophytic from the parasitic fungi, the service of a microbiologist is necessary. This service has not been available in Ohio, therefore, the exact status of the two groups of fungi in their relation to dead larvae and pupae is not known. However, each season (Table 4) in both the natural cocooning quarters and in rearing cages, dead larvae and pupae may be found with their bodies covered by fungi. Some degree of control is secured through these fungi but they usually develop too late in the season and such small numbers of larvae are attacked that the part they play is of minor importance.

CHEMICAL CONTROL

Even though all factors unfavorable to the codling moth could be brought to bear against it, the production of a commercial crop of apples in Ohio would be impossible without the use of chemicals applied usually as sprays. The spray program that is now necessary in insect and disease control has been evolved during the last seventy-five years, and is now very effective but also complex and expensive (9). These two disadvantages have forced the abandonment of many acres of apple orchards in Ohio.

To make the use of spray chemicals most effective, a number of factors must be considered and used to best advantage. A brief discussion of each of these follows:

Effective Spray Material The very large number of insecticides and acaricides (miticides) which are available for use make the selection of materials a rather difficult but important matter. The most effective insecticides should be used even though these may be somewhat more expensive and difficult to handle. For example, in an orchard where the codling moth is resistant to lead arsenate, it would be foolish to use this material when Guthion or carbaryl (Sevin) would be much more effective. Parathion and other organic phosphate compounds are more dangerous to handle, but if they are more effective it will pay the grower to equip himself with safety mask and goggles, and using all safety measures, to spray with these materials. Information regarding the effectiveness of spray materials may be secured from current spray schedules, from extension and research personnel and from orchardists who have had experience in their use.

Correct Dosage As a general rule, the maximum dosage recommended by the manufacturer or the extension servise should be used. This should insure a high mortality among the pests with consequent favorable results both in the decrease of immediate damage and ease of future control. The use of the maximum instead of the minimum dosage will, of course, be more expensive but better results are usually well worth the difference. Also, the higher the mortality the less rapid will be the development of resistance.

Complete Coverage The use of effective spray material and correct dosages are essential but even these great advantages will be lost if other factors are neglected. Of these, complete coverage is highly important. This means that every leaf and fruit should be covered by the spray. If not, many insects will escape and form a base for future trouble. Special care should be taken to cover the tops and insides of the trees. To secure complete coverage, it is frequently recommended that a gallon of spray be used for each year of the tree's age, especially after it comes into bearing. However, a special study of spray practices among Ohio growers has shown that good results may be secured with 0.7 to 0.8 gallon per each year of the tree's age; and in some cases, that even a smaller amount may be used if skilled spray men are employed. For example, one grower who was highly skilled in the application and distribution of spray over the tree was producing clean fruit with about 0.5 gallon per year of the tree's age. However, this was an exceptional case. Growers using less than 0.5

gallon per tree year are usually in trouble with either insects or diseases and frequently with both. When high capacity sprayers, equipped with mechanical booms, air blast, or other automatic devices are being used, nozzles and boom adjustments must be made for trees of different sizes. This is especially important in securing adequate coverage of the tops of the trees. Complete coverage is essential.

Correct Timing The efficiency of modern insecticides has made the necessity for exact timing less important than formerly. However, every orchard has certain situations that, for effective solution, will need the personal attention of owner or manager to determine proper timing.

Spray Machinery No differences in codling moth control have been noted that were due to the use of different types or brands of spray applicators. This is true, provided that effective chemicals were used and that the rules for adequate dosage, complete coverage and correct timing were followed. In fact, good fruit may be grown if the foregoing rules are observed, even though sprayers are of low capacity and poorly designed. The great advantage of the sprayer that is equipped with a high capacity pump is that time and labor are saved. With a low capacity pump, say from 12 to 15 gallons per minute, four to five times the amount of time and labor are required for thorough spraying of the trees. However, if the time and labor requirements are met, good results may be secured. The importance of nozzle adjustment has already been mentioned.

In any event, every orchard should have available spray machinery adequate for the job of covering the entire planting within a period of three or four days. This will meet present-day requirements of timing.

Ohio tests with dusts applied either with ground equipment or from airplanes have not been successful. Also, the application of sprays from the air have not given adequate insect or mite control.

CONCLUSIONS

From statements and data in Ohio horticultural and entomological literature and from the personal experiences of entomologists who have worked with the codling moth during the last 40 years, the following conclusions may be drawn:

(1) The codling moth was introduced into Ohio as larvae in infested fruit or as cocooning larvae in boxes or baskets.

(2) The date of first codling moth injury in Ohio is not known. Apparently it was observed in the eighteen-thirties or early forties. By the time of the Civil War (1861) it was severe in some orchards.

(3) Despite the early date of introduction and serious injury in some areas, many small and isolated orchards remained relatively free from codling moth injury until the early eighteen-nineties.

(4) Codling moth injury has influenced commercial apple production and has been one of the factors that caused the abandonment of the industry in several sections of the state.

(5) The decline and disappearance of the farm orchard was due to increased ravages of insects and disease. The codling moth was a definite factor in this loss.

(6) The control of apple pests in Ohio has always been of interest to horticulturists, horticulture societies and to entomologists.

(7) The correct interpretation of ecological data as related to the codling moth necessitates an accurate knowledge of the life history of the insect.

(8) Among the ecological factors, seasonal temperatures are very important in the rate of development of codling moth infestations.

(9) Other climatic factors such as humidity, rainfall, and wind play a part but are far less important than temperature.

(10) Natural enemies, including predators, parasites, and diseases may at times be effective but generally are of little importance in the control of the codling moth.

(11) Orchard management is important. This includes such practices as sprayng, pruning, sanitation and harvest practices.

(12) Successful control of the codling moth is a product of:
- (a) An efficient spray program
- (b) Climatic conditions unfavorable to the insect
- (c) Good orchard management
- (d) Low initial codling moth population

(13) An efficient spray program is the most important of all factors for successful control.

1. Brooks, F. E. and E. B. Blakeslee. 1915. Studies of the codling moth in the central appalachin region. U.S.D.A. Dept. Bull. 189:46.
2. Chandler, S. C. 1946. Codling moth control. Illinois Agric. Exp. Sta. Bull. 519.
3. Clancy, D. W. and N. H. Pollard. 1952. The effect of DDT on mite and predator populations in apple orchards. Jour. Econ. Ent. 45:108-113.
4. Cox, J. A. 1932. **Ascogaster carpocapsae,** Vier., an important larval parasite of the codling moth and oriental fruit moth. N.Y. Agric. Exp. Sta. Tech. Bull. 188:1-26.
5. Cutright, C. R. 1931. Some laboratory reactions of young codling moth larvae. Jour. Econ. Ent. 24, 81-83.
6. Cutright, C. R. 1937. Codling moth biology and control investigations. Ohio Agric. Exp. Sta. Bull. 583.
7. Cutright, C. R. 1953. Grower control of the codling moth. Ohio Agric. Exp. Sta. Bull. 720.
8. Cutright, C. R. 1954. A codling moth population resistant to DDT. Jour. Econ. Ent. 47(1):189.
9. Cutright, C. R. 1955. Increasing complexities in the apple spray program. Jour. Econ. Ent. 48(3):304-306.
10. Cutright, C. R. nd H. E. Morrison. 1935. Varietal susceptibility to codling moth attack. Jour. Econ. Ent. 28:107-109.
11. Dutky, S. R. and W. S. Hough. 1955. Notes on a parasite nematode of the codling moth larvae, **Carpocapsa pomonella.** Jour. Ent. Soc. Washington 57:244.
12. Dutky, S. R. 1959. Advances in applied microbiology. Academic Press, N. Y. 1:175-200.
13. Felt, E. P. 1910. Recent experiments with the codling moth. Jour. Econ. Ent. 3:476.
14. Glenn, P A. 1922. Codling moth investigations of the state entomologists office. Illinois Nat. History Survey. Bul XIV Art. VII.
15. Hamilton, D. W. 1956. Resistance of the codling moth to DDT sprays. Jour. Econ. Ent. 49(6):866.
16. Hamilton, D. W. 1958. Effect of insecticides on codling moth larvae seeking cocooning quarters. Jour. Econ. Ent. 51(5):672.
17. Hammer, A. G. 1912. Life history studies on the codling moth in Michigan. U.S.D.A. Bur. Ent. Bull. 115, Part I:73.
18. Hough, W. S. 1928. Relative resistance to arsenical poisoning of two codling moth strains. Jour. Econ. Ent. 21:325-329.
19. Hough, W. S. 1934. Colorado and Virginia strains of codling moth in relation to their ability to enter sprayed and unsprayed fruits. Jour. Agric. Res. 48:533-553.
20. Hough, W. S. 1943. Development and characteristics of vigorous or resistant strains of codling moth. Virginia Agric. Exp. Sta. Tech. Bull. 91.
21. Isely, D. and A. J. Ackerman. 1923. Life history of the codling moth in Arkansas. Ark. Agric. Exp. Sta. Bull. 189.
22. Isely, D. and H. H. Schwardt. 1936. Variation in codling moth injury in northwestern Arkansas. Jour. Econ. Ent. 29:473.

23. Lloyd, W. A., J. I. Falconer and C. E. Thorne. 1918. The Agriculture of Ohio. Ohio Agric. Exp. Sta. Bull. 326.
24. Lord, F. T. 1956. Influence of spray programs on the fauna of apple orchards in Nova Scotia. Canadian Ent. 88:129.
25. MacLellan, C. R. 1959. Woodpeckers as predators of the codling moth in Nova Scotia. The Canadian Entomologist 91(2):673-680.
26. MacPhee, A. W. 1953. Influence of spray programs on the fauna of apple orchards in Nova Scotia. Canadian Ent. 85:33.
27. Matthews, W. H. 1942. The story of Ohio horticulture. Proc. Ohio State Hort. Soc. 1942. pp. 276-431.
28. Nel, R. J. 1941. Varietal interplanting in relation to control of the codling moth. Ent. Soc. of Southern Africa 4:111-134.
29. Nel, R. J. 1942. Biological control of the codling moth in South Africa. Jour. Ent. Soc. of Southern Africa. Sept. 118-137.
30. Newcomer, E. J. 1924. Control of the codling moth in the Pacific Northwest. U.S.D.A. Farmers Bull. 1326.
31. Pickett, A. D. 1946. Influence of spray programs on the fauna of apple orchards in Nova Scotia. Sci. Agric. 26:590-600.
32. Porter, B. A. and L. F. Steiner. 1928. The codling moth in Indiana. Ind. Agric. Exp. Sta. Cir. 151.
33. Selkregg, E. R. and E. H. Siegler. 1928. The life history of the codling moth in Delaware. U.S.D.A. Tech. Bull. 42.
34. Shelford, V. E. 1927. An experimental investigation of the relations of the codling moth to weather and climate. Illinois Nat. History Survey Bull. XVI.
35. Smith, W. W., L. Jenkins, and L. Haseman. 1943. A study of codling moth abundance as influenced by crop failures. Missouri Agric. Exp. Sta. Bull. 472.
36. Steinhaus, E. A. 1949. Principles of insect pathology. The McGraw-Hill Book Co. pp. 318-416.
37. Webster, R. L. 1934. Arsenic deposit and codling moth control. Jour. Econ. Ent. 27:410-417.
38. Yothers, M. A. and F. W. Carlson. 1949. Scraping and banding apple trees as a supplementary codling moth control measure in the Pacific Northwest. U.S.D.A. Cir. No. 828.

THE CODLING MOTH IN OHIO

Historical and Ecological Aspects

APPENDIX

Chronological Record of Codling Moth Infestations 1926-1963

1926: Spring generation moths appeared later than average and this was reflected in a late peak of both first and second-brood larvae. Midsummer moths were late also, both in first appearance and in peak of abundance. Temperatures for this season were below normal for all months except August and September, and in the latter there was only a slight elevation. Codling moth was not difficult to control.

1927: A severe freeze during the last week of April seriously damaged fruit in central Ohio and practically destroyed the crop in the southern counties. Northern Ohio was not affected. Temperatures were below normal for June, July, and August. The first appearance of moths and larvae for all broods was later than normal as were the periods of greatest abundance. Little difficulty was encountered in controlling the insect. Also, the crop loss in many orchards in southern Ohio greatly reduced the codling moth population, although an open fall aided late worms in getting into hibernation.

1928: With the exception of July, monthly mean temperatures were below normal. A large crop was harvested in practically all commercial orchards. The first appearance and the peak of the different stages of both broods were in all cases later than the usual date. The insect was easily controlled.

1929: Early April temperatures were well above norml, and this condition was reflected in southern Ohio by the earliest emergence and peak of spring-generation moths on record. In northern Ohio, however, April temperatures were not sufficiently high to offset the effect of a cool May and June. At Wooster, moth activities for all broods were nearly normal; whereas in northwestern Ohio they were generally late. July was about noraml as to temperature, and August was below normal. At the end of the season, codling moth was at such a low ebb that Ohio entomologists considered abandoning research on the project.

1930: This was the first of the five so-called drought years in which temperatures were generally above normal and rainfall was deficient; in fact, the worst drought of years was experienced. Temperatures were in excess of the average every month of the growing season. All stages of codling moth appeared earlier than usual, and were so accelerated that by the latter part of the season larvae were present in such numbers that they not only caused a great deal of damage, but also provided an overwintering population greatly in excess of normal.

1931: Codling moth activity during May and June was almost normal, but second-brood larvae appeared in great abundance and caused much damage to fruit. Rainfall was slightly above average for the growing season as a whole, but was deficient in June and July. Temperature was about normal during April, May, and June but was far above the average in July and August.

1932: This was another season of deficient rainfall and excess temperature. The latter, however, was more nearly normal than in

1930. Excess temperatures were registered in every month except April. Spring-brood moths appeared slightly later than normal but emergence was so rapid that the peak was about 6 days earlier than usual. From this point on, all stages were slightly advanced. Codling moth damage was severe, especially in southern Ohio and along western Lake Erie. Poisoned bands were used in a few orchards for the first time.

1933: Rainfall for the growing season showed a deficit of about 2 inches, and temperatures were greatly in excess of normal for the entire season. Codling moth appeared early, increased greatly during the summer, and was the worst problem of the year. A light crop in some orchards made the amount of injury especially noticeable.

1934: The season began with a cool April but this was followed by 3 very warm months. August was near normal and September was again above the average. Rainfall was almost normal and was well distributed except for a very dry May. Codling moth emergence started and peaked very early, and larvae first appeared at the earliest date on record. There was heavy codling moth damage, especially in southern and northwestern Ohio. The highest percentage of injured fruit ever to be noted was observed in the horticultural orchards at Wooster.

1935: After five hot, dry seasons, 1935 reverted to the pattern of 1928. April, May, and June were much cooler than normal. Codling moth activity started slowly, with moths and other stages appearing from 7 to 10 days later than normal. Even the excess temperatures of July and August failed to bring the insect to a point where noticeable damage occurred. Although temperature conditions and codling moth injury were very similar to those of the season of 1928, there was a great difference in the amount of rainfall. Approximately 31 inches of rain fell during the growing season of 1935, mostly in July and August; whereas in 1928 there were only 18 inches.

1936: This season started with a very low codling moth population in all sections of the state. April was cool but the temperatures of May, June, and July were all above normal. Rainfall was generally deficient. Early first-brood larvae established themselves in considerable numbers and from these came a second brood large enough to cause increased injury. In general, the insect may be said to have staged a definite recovery with an increase in overwintering population large enough to menace the crop of 1937, if weather conditions favorable to the insect prevail.

1937: Weather conditions, except for a brief period in late May and early June, were unfavorable for the codling moth in northern

Ohio. In southern Ohio, August was warm and dry and this condition, plus a rather short spray schedule, produced severe codling moth injury in numerous orchards. Injury in Lucas and Ottawa Counties was also severe. In other sections of the state, injury was about normal. Experimental work with various non-lead arsenicals, which had been in progress since 1934, was terminated. The final conclusion was that they could not be safely used in Ohio orchards.

1938: Codling moth emerged early but egg deposition, hatching and larval establishment were hindered by frosts and general low temperatures in May and June. In general fair control was secured by most growers but severe injury was experienced in several orchards, especially in the Toledo area and in southern Ohio. This year marked the first extensive use of oil in combination with lead arsenate. As no buffering agents were used with this combination, severe foliage injury occurred in many orchards.

1939: Following cool weather in early May, a period of high temperatures produced a mass emergence of codling moths within a few days. Large numbers of eggs were laid but as these were hatching in early June, cold weather for a period of about 10 days prevented many young larvae from entering the fruit. This was a great aid to growers and control of the codling moth was good in most orchards. Lead arsenate – oil, plus zinc sulphate was used for the first time and gave good results. Also, nicotine – oil combinations were extensively tested in experimental work.

1940: Weather for the growing season of 1940 was near normal both as to temperatures and rainfall. Codling moth infestations for the year were more severe than in 1939 but not as damaging as in in 1937. Lead arsenate was reinforced in many cases with summer oil or different forms of nicotine. However, none of these schedules was entirely satisfactory, due either to heavy residues of the insecticide, phytotoxicity, or cost.

1941: Temperatures for April, May, June, July, and September were all above normal, with those of September being especially high. Conditions were favorable for both broods of the codling moth and the most severe damage since 1934 was encountered. Injury to 80 percent of the crop was experienced in one orchard in Lawrence County. Orchards in southwestern, northwestern, central, and the area along Lake Erie west of Cleveland, generally suffered severe losses. On the other hand, most orchards in northeastern Ohio produced a clean crop.

1942: The increased populations of codling moth, which resulted from favorable conditions in 1941, took advantage of favorable early season weather (high temperatures in April, May, and June) and an infestation of even greater magnitude than that of 1941 resulted. This was especially noticeable along Lake Erie and in northwestern Ohio. Despite this fact, some orchardists in these areas produced a crop 99 percent free of codling moth. (See 1943 Proceedings, Ohio State Hort. Soc. pp 33-35.)

Experimental work in 1941-1942 stressed the use of different nicotine products, used alone and in combination with oil and sticking agents. Results were good in some cases but cost was a barrier to general use.

1943: A light crop in 1943 added to the difficulties of codling moth control. Low temperatures in April and May delayed the insect but June was 5° F above normal. This enabled the codling moth to regain lost ground and the first larvae left the fruit at a date earlier than average. Temperatures were about average for the months of July, August, and September. The summer season was also quite dry. Numerous growers were successful in codling moth control but others suffered severe losses. In general, codling moth injury was above average.

1944: This was another season with a crop of only medium size and temperatures favorable to the codling moth. Only the better growers or those in favorable areas succeeded in producing a high percentage of worm-free fruit. To illustrate the severity of the infestation, 17,093 larvae were collected from 115 banded trees in the Frank Farnsworth Orchard at Waterville, Ohio. In 1944 the first commercial use was made of the "speed" or air blast sprayer in Ohio orchards; also, the first trial use of DDT in the control of codling moth where it was highly successful. The ecological work in the orchards of Ottawa County which extended over a five-year period, and which is reported in OAES Research Bull 720, "Grower Control of the Codling Moth", was also started during this season.

1945: A very warm March and April produced extra early blooming of apples. During the bloom period, severe frosts occurred which resulted in one of the smallest Ohio apple crops on record. Weather during the summer months was not favorable to codling moth but due to the very light crop a higher percentage of fruit was injured than in 1944. Experimental work with DDT was increased in amount

and excellent control was secured with this material. Some DDT was secured by growers and successfully used. These results were reported in the Proceedings of the Ohio State Hort. Soc., 1946.

1946: The general use of DDT by practically all growers who were having difficulty in codling moth control, plus cool weather in May and June reduced codling moth injury to the lowest point in years. The chief problem of the year was the control of the European red mite and extensive experiments designed to suppress this pest were started. Despite the continuation of such tests in every season, up to and including that of 1963, the problem of mite control continues to be of major importance.

1947: Increasing use of DDT plus temperatures below normal in May, June, and July kept the codling moth well in check especially for the period of the first brood. High temperatures in August and September increased injury by the second brood in some orchards. Parathion was used experimentally for the first time.

1948: Low temperatures prevailed during most of the season and generally codling moth was well controlled. However, warm weather occurred in late August and where no mid-August spray was applied, there was an increase in wormy fruit. Also, the light crop of fruit produced in many orchards caused a relatively higher percentage of the fruits to be injured. Spray rigs adapted for applying concentrate sprays were used in experimental work and very good results secured.

1949: A large crop of fruit relatively free from codling moth and other insect injuries was produced despite the fact that weather conditions were more favorable for the codling moth than in 1947-1948. Parathion was applied in several orchards and concentrate sprayers were first used commercially.

1950: Codling moth was well controlled during this season except in certain orchards. For example, numerous wormy apples were found in the orchard of the Hamilton County Experiment Farm. At this time, it was thought that the change in farm managers, which caused some confusion in spraying, was to blame for this condition. However, later events showed that this was probably the start of DDT resistance in this orchard. Too much injury was also reported by the Dayton State Hospital and the Frank Farnsworth Orchards at Waterville. Large old trees carried most of the injured fruits. The crop of 1950 was much smaller than that of 1949.

1951: May and June had temperatures slightly above normal but the other months of the growing season were somewhat below.

The crop was much larger than in 1950 and excellent control of codling moth was secured in most orchards.

1952: A short crop plus high temperatures for the season caused a marked increase in codling moth infestation. For example, in one orchard in 1951, 2.7 percent of the fruit was injured by codling moth while in 1952, using the same spray schedule, the injured fruit amounted to 10.7 percent. The infestation was especially severe in several orchards in southwestern Ohio and resistance to DDT was suspected. Parathion was used in sections of certain orchards and codling moth control was secured in these, whereas wormy fruits were very prevalent on DDT sprayed, adjacent trees.

1953: Better control of codling moth was secured in 1953 even though early season temperatures were above normal. The probable reason for this is that the crop was larger thus diluting the injury. Resistance on the part of codling moth to DDT in the Cincinnati area was definitely proven by a field experiment at the Hamilton County Experiment Farm. Also, mites in the Clyde, Ohio area were shown to be resistant to parathion.

1954: Codling moth injury was more severe than in any season since the introduction of DDT (1947). This was due largely to very warm weather starting in early June and lasting the rest of the month. High temperatures in late August and in September also favored the 2nd brood of the codling moth. Some additional orchards in southwest Ohio reported difficulties in controlling with DDT. Diazinon and Ryania were used experimentally for the first time.

1955: Practically all growers were succesful in codling moth control. In southern Ohio, DDT reinforced with parathion, was widely used, while in northern Ohio, lead arsenate followed by DDT was effective. Low temperatures in June also helped. Carbaryl (Sevin) was used experimentally for the first time and gave excellent control.

1956: Cool spring and summer weather delayed codling moth activity and this in connection with a good spray program gave good general control of this insect. However, from southern Ohio there were additional reports of the failure of DDT to control. In experimental work, Guthion was used for the first time in Ohio and gave excellent results. Work was continued with carbaryl (Sevin) and again the results were excellent.

Laboratory tests at Vincenes, Indiana with the progeny of larvae from the Hamilton County plots proved a high degree of resistance to DDT.

1957: For the third successive year seasonal temperatures were below normal and codling moth control was good. Records indicate that codling moth populations are now at the lowest point in the past 30 years, except in some orchards in southern Ohio where DDT-parathion is failing to control. Carbaryl (Svin) and Guthion continue to give excellent control in experimental work.

1958: Another year of successful codling moth control. Carbaryl (Sevin) and Guthion were used commercially for the first time in a few orchards with excellent results. Also, cool weather in late June and early July aided in control. In the Columbiana and Mahoning Counties area, DDT was still effective.

1959: The low initial population, due to good control in several past seasons, aided control even though the season was warmer than average. Control in general was quite good though several orchards, mostly in southern Ohio, suffered severe losses due to the failure of DDT or DDT-parathion to control. The use of carbaryl (Sevin) and Guthion increased and where used excellent control was secured.

1960: Temperatures were low in early season and excellent control of first brood codling moth was secured. Influenced by this happy condition, some growers neglected to apply all sprays against the second brood. Since very warm weather prevailed in late August, and early September, codling moth increased in these orchards. Growers who applied the recommended numbers of sprays maintained excellent control. The use of Guthion increased.

1961: Seasonal conditions were unfavorable to the codling moth and excellent control was secured in practically all commercial orchards. Other insects were also of minor importance and one of the "cleanest" crops on record was harvested. Large quantities of Guthion were used as well as additional amounts of carbaryl (Sevin).

1962: Despite weather favorable to the codling moth, the crop of 1962 was even better than that of 1961, as far as insect control was concerned. Effective spray materials were used by most growers. That the codling moth was still present was shown when two growers used a lead arsenate schedule which resulted in considerable injury by this species.

1963: The winter of 1962-63 was one of the coldest on record in Ohio. This caused a very high mortality of overwintering larvae and a greatly reduced number of emerging moths of the spring brood. However, in unsprayed and poorly cared for orchards many fruits were infested. Even in orchards that sprayed regularly during the early part of the season but neglected the late spray applications enough codling moth injury appeared to show that control could not be neglected. In general temperatures during the growing season were unfavorable for the insect except for the month of July which was above normal. The conditions of this season emphasize the fact that the codling moth is always present and always a threat to the production of clean apples.